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Measuring spatial disparity in accessibility with a multi-mode method based on park green spaces classification in Wuhan, China

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ABSTRACT

Limited accessibility measurements of park green spaces (PGSs) have given an account of multiple transportations when people enjoy the services. Considering the varying types and functions of PGSs, this study proposed a multi-mode method that is based on the traditional two-step floating catchment area method and relied on PGS classification to estimate spatial disparity between the supply of PGSs services and residents' demands in accessibility. Choosing the urban center of Wuhan as the study area, comparative analysis of space and statistics were conducted in accessibility between the traditional single-mode and the multi-mode methods. After a sensitive analysis of accessibility with varying travel time thresholds, underserved areas in the urban center were identified on a community level based on the PGS groups. Results indicated that the estimated accessibility average and standard deviation values by single-mode method were slimly higher than that of the multi-mode method. The average and standard deviation values of the accessibility among five time thresholds exhibited slight difference and an increasing trend. The further examination analysis of spatial accessibility in 25-min threshold demonstrated that accessibility presented spatial polarization and that most underserved areas distributed in the eastern and southwestern of the urban center in Wuhan. The findings may provide a more realistic estimation and further the knowledge of access to green spaces to help decision makers developing equal and effective planning policies and strategies.

1. Introduction

Park green spaces (PGSs) are indispensable public infrastructures because of their benefits to urban residents; such benefits include recreation, viewing ecology, disaster prevention, and improved quality of life (Chiesura, 2004; Smith, Case, Smith, Harwell, & Summers, 2013; van Kamp, Leidelmeijer, Marsman, & de Hollander, 2003). However, PGSs are often unequally distributed in urban areas and the disparity of access to these green spaces has been considered as a problem in urban areas for long (Boone, Buckley, Grove, & Sister, 2009; Wolch, Wilson, & Fehrenbach, 2013). The spatial disparity between the provisions of PGSs and the needs of residents has become increasingly concerned in developed (Lee & Hong, 2013; Nicholls, 2001; Wendel, Downs, & Mihelcic, 2011) and developing (Yao, Liu, Wang, Yin, & Han, 2014; You, 2016) countries.

Access to green spaces is a vital element in measuring the disparity between their supply and people needs for urban green space planning (Dony, Delmelle, & Delmelle, 2015; Lee & Hong, 2013; Oh & Jeong, 2007; Wendel et al., 2011). People in densely populated regions consider access to parks convenient when their high demand for green spaces is met. Earlier studies suggested that accessibility to parks relied on whether or not the spatial distribution of its provisions conforms to the demand of the population (Nicholls, 2001; Oh & Jeong, 2007; Wolch et al., 2013). Several studies afterwards have emerged to employ accessibility to investigate the disparities of PGSs services in urban areas among different population groups, such as socioeconomic, racial, and religious groups (Comber, Brunsdon, & Green, 2008; Crawford et al., 2008; Dai, 2011). Although empirical results vary, the disparity between the supply and demand of public green spaces is detected comprehensively in these studies. Aside from accessibility, the quality of green spaces is another factor that affects people's perceived benefits of PGSs (Gupta, Kumar, Pathan, & Sharma, 2012; Wright Wendel, Zarger, & Mihelcic, 2012; Yao et al., 2014). In quantifying the provision of green spaces, previous studies concerned the size and per capita area indexes more but limited to consider their functions and characteristics. Ibes (2015) took the physical and spatial characteristics of parks, land cover, built and social context into account in reclassifying the green spaces as well as equality analysis, thereby providing a better

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perspective for equality studies. Therefore, quality and accessibility indexes are important factors that the disparity of PGSs will be examined in terms of quality and accessibility based on classification in this study.

A variety of spatial accessibility measurements have been employed to evaluate access to public services. Initial methods called container approaches identify whether a park located within a geographic unit (for example, a community) easily obtains a high access score in a large unit because its evaluation is based on unit size (Dony et al., 2015). The alternative coverage methods such as buffer analysis (Nicholls, 2001), kernel density estimation (Moore, Diez Roux, Evenson, McGinn, & Brines, 2008), and network constrained service area methods (Miyake, Maroko, Grady, Maantay, & Arno, 2010) identify the population within the area with a specified distance. They are also considered slightly arbitrary due to the difficulty in determining predefined distance (Dony et al., 2015). Thiessen polygons method identifies the potential crowding and underserved areas in a region on the assumption that all individuals select the closest public facility around their residence. This may not be realistic for public parks in which residents prefer a larger regional park far from them (Boone et al., 2009; Sister, Wolch, & Wilson, 2009). Later gravity-based models overcome this problem by incorporating concepts of attraction and friction to estimate the tendency of traveling to a specific location (McCormack, Rock, Toohey, & Hignell, 2010). However, the incorporation of overall destination choices tend to overly smooth accessibility values (Mcgrail & Humphreys, 2009).

As a dichotomous technique of gravity-based models, the two-step floating catchment area method (2SFCA) is regarded as a suitable approach to measure potential spatial accessibility and has been widely used in health care access studies (Bissonnette, Wilson, Bell, & Shah, 2012; Cervigni, Suzuki, Ishii, & Hata, 2008; Fransen, Neutens, De Maeyer, & Deruyter, 2015; Luo & Wang, 2003). This method evaluated potential spatial accessibility in light of the acceptable maximum distance of individuals but along with the limitation of distance decay. Improvement methods such as the enhanced 2SFCA (Luo & Qi, 2009) and the Gaussian-based 2SFCA (Dai, 2010, 2011) have been introduced to address this limitation. However, all these methods defined each catchment area within a fixed distance considering the size of facilities but neglected their types and attractiveness, which is not in line with the realistic of park planning. Wang (2012) suggested that spatial accessibility measurements differed in ways of conceptualizing the distance decay effect and one had to analyze the real-world travel pattern in order to derive the best fitting distance decay function. Dony et al. (2015) developed a variable-width floating catchment area method considering both the size and number of amenities to estimate accessibility by four traffic modes and found that outlying suburban people preferred to larger regional parks while center urban residents favored of plentiful park amenities. This provides a new perspective of improvement for accessibility evaluation in a more reality way.

The traditional methods discussed above rely on an intrinsic assumption that all residents get to public facilities especially parks by a single transportation mode, such as walking (Miyake et al., 2010), biking (Wendelvos et al., 2004), public transit (Meek, Ison, & Enoch, 2011) and cars (Dai, 2011), as well as their comparing studies (Clayton, Ben-Elia, Parkhurst, & Ricci, 2014). However, this assumption is unrealistic for different population groups that preferred varying traffic modes, such as low-income population groups who do not own cars or metropolitan residents who favor public transportation because of parking issues. Overlooking multiple transportation modes, the measures would inevitably accompany some errors when estimated the accessibility. Wang (2013) early attempted to assess and integrate spatial access by two modes of public transit and cars to measure workers' location advantage to their job markets. Mao and Nekorchuk (2013) proposed a multi-mode 2SFCA method to estimate the accessibility to healthcare and conducted a comparison with cars, but surveys or census data of the subpopulations division by mode may not be easily obtained in some cities. Moreover, comparing the driving mode only is inadequate because residents use specific transportation modes for specific purposes (for example, people choose walking or cycling for exercise and driving to go to parties with friends). To date, little attention has been given to consider multiple transportations in accessibility measures in urban green space research. Therefore, exploring accessibility measures with multiple transportations may be a meaningful research in identifying more realistic underserved areas to achieve effective planning and policy decision making.

As a supplement research to spatial disparity of urban green space, this study takes account multiple traffic modes to the traditional 2SFCA method and calculates service provisions based on varying park levels, to evaluate the spatial disparity in accessibility of people to urban PGSs in the urban center of Wuhan, China. As an economic, political, and cultural center in central China with unprecedented growth and expansion, Wuhan is the chosen place of study because it has an integrated green space planning system that is nevertheless experiencing a tremendous green space loss similar to many cities in China. The different sections of this paper are as follows: section 2 reviews the conventional 2SFCA method and describes the multi-mode 2SFCA method based on PGSs classifications in detail. Section 3 illustrates the study area and data preparation, as well as the reference standard of the important parameters of the proposed method. Section 4 shows the results of comparison analysis and then further identifies the service-deficiency areas. Specifically, results of the spatial distribution and statistical comparison among three single-modes and the multi-mode accessibility are presented. Results of the comparison of the spatial accessibility under varying travel time thresholds are also shown. Section 5 discusses the comparison results and the arguments in this study; and the last section concludes our findings.

2. Methods

2.1. The traditional 2SFCA method

The 2SFCA, which was first proposed by Radke and Mu (2000) and later modified by Luo and Wang (2003), is a special case of gravity model based on a threshold travel time. The method is implemented by a two-step procedure. First, the overall demand location i is searched within a threshold travel time t_0 for each public facility j, and then the populations for j are summarized to compute the service-to-population ratio R_j. Second, search the overall facility locations within t_0 for each demand population i, and service-to- population ratio R_j is summed up to calculate the spatial accessibility A_i at demand location i as the following equation:

$$A_i = \sum_{l\in\{t_{ij}\le t_0\}} R_j = \sum_{l\in\{t_{ij}\le t_0\}} \frac{S_j}{\sum_{k\in\{t_{ij}\le t_0\}} P_i} \quad (1)$$

where P_i is the population at location i within the catchment ($t_{ij} \le t_0$) from public facility j; t_{ij} is the actual travel time from i to j; and S_j is the capacity of public facility j.

This method assumes uniform access within a catchment reckoning without distance decay and obtains relative unrealistic results. Luo and Wang (2003) first used a travel-friction coefficient β as a distance decay parameter to improve the gravity-based model and the 2SFCA method, and proved that the former method tended to obtain higher accessibility scores in low-accessibility areas and ignore the underserved areas. Wang (2006) and Yang, Goerge, and Mullner (2006) also obtained a similar conclusion. Luo and Qi (2009) proposed an E2SFCA method to identify more underserved areas by dividing a catchment into some weighted zones, but unchanged the assumption of uniform accessibility within a travel time zone. Dai (2010) integrated the 2SFCA method with a Gaussian function to estimate accessibility discounting accessibility continuously and obtained better results without dividing the catchment as follows: